Feb. 24, 1984 A/B Not Filmed

R5650-2A

JAPAN · ECONOMIC · INSTITUTE

JEI

REPORT

NO. 9A March 2, 1984

U.S.-JAPAN COMPETITION IN ROBOTS: AN UPDATE

Summary

Although American companies pioneered the robotics field, Japanese manufacturers have become the production leaders. Support from factory managers for the introduction of robots plus products tailored to simple, practical applications have enabled Japanese robot makers to build a broad base of customers. U.S. robot producers have been stymied in their efforts to expand the user market by management resistance to this form of automation as well as by the recession. These constraints have not kept new American competitors from crowding into the market. Many of these newcomers have tied up with Japanese makers, providing themselves with low-cost entry into the domestic robotics business and giving their offshore partners quick market access.

Widening Production Gap

Although robots have been manufactured in the United States for a quarter century and in Japan for 16 years, studies of the competitive position of the two countries' industries continue to be handicapped by the absence of a commonly accepted definition of this industrial device. The Robot Institute of America (RIA) -- a trade association of robot manufacturers, distributors, peripheral equipment suppliers and corporate users -- defines a robot as a "reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks." The RIA's Tokyo counterpart, the Japan

Industrial Robot Association (JIRA), uses a broader definition, one that includes manipulators operated by humans and "dedicated" or non-programmable equipment.

Different robot classifications also hinder international comparison. JIRA categorizes robots in terms of their operating systems. This procedure results in six types of robots, two of which -- manual manipulators and fixed sequence robots -- are not considered robots in the United States. The other four are described in different terms here, yielding a match-up between variable sequence robots and pick-and-place robots, playback robots and programmable robots, numerically controlled robots and computer-controlled robots, and intelligent robots and sensory robots.

A more frequently used classification in this country, though, is one based on the robot's control mechanism. It differentiates between nonservo-controlled robots, which are only capable of straight-line movements -- up-down, left-right, in-out, and servo-controlled robots, which can be programmed to any position within their operating range or can perform point-to-point operations. Found in the United States as well is a classification system that divides robots by their principal end uses or applications, including materials handling, machine loading and unloading, spot and arc welding, spray painting and coating, and assembly.

Definitional and classification problems notwithstanding, there is no question that Japanese robot manufacturers are outproducing their American competitors across the board. The Robot Institute of America pegged U.S. production of robots in 1982 at 1,601 units valued at $195 million, up from 1,269 units costing $155 million the year before and a 1980 output of $101 million. Using its broader definition, the Japan Industrial Robot Association calculated that in-country production hit 24,782 devices in 1982 worth Y148.4 billion ($596 million), compared with a year-earlier outturn of 22,069 units tagged at Y107.8 billion ($486.7 million) and 1980 results of 19,873 units valued at Y78.4 billion ($345.9 million). Switching to the American definition of robots does not change the observation that Japan is pulling ahead of the United States since, on this basis, Japanese robot production climbed from 4,493 units worth Y49.3 billion ($217.3 million) at the start of this decade to 14,937 units costing nearly Y118 billion ($493.6 million) two years later.

The result of this widening production gap is clear cut: the number of programmable robots in operation in Japan dwarfs the U.S. robot population. According to a recent U.S. International Trade Commission (ITC) study of the robotics industry, Japanese manufacturers had installed 31,900 robots by the end of 1982, more than tripling their 1978 base. American companies, in contrast, expanded their robot usage two-and-a-half times over this five-year period, but they still had only 7,200-plus units in operation at year-end 1982. The U.S. tally, however, was higher than West Germany's, the European leader with some 3,500 robots in operation.

Lagging U.S. Demand, Buoyant Japanese Market

The robotics business has expanded not only quicker in Japan than here but also at a faster pace than JIRA thought possible in the late 1970s. Year

The JEI REPORT (ISSN 0744-6489) is published weekly for $40 per year by the Japan Economic Institute of America, 1000 Connecticut Avenue, N.W., Washington, D.C. 20036. Second class postage paid at Washington, D.C. POSTMASTERS: Send address changes to JEI, 1000 Connecticut Avenue, N.W., Washington, D.C. 20036.

after year the trade association has come up short on its market forecasts. Industry analysts in the United States have had the opposite problem. Sales projections made in the late 1970s have been at least two years off the mark and sometimes five years off base, as the explosive growth rates forecast then for the first part of the 1980s have failed to materialize. Recent estimates place the 1982 domestic robot business somewhere between $175 million and $195 million and the 1983 market in the neighborhood of $240 million. But even these scaled-back numbers may be on the high side, the ITC concluded after surveying U.S. manufacturers, traders and buyers last year for its robotics study (see Table 1).

The recession-triggered slump in U.S. capital spending has obviously curbed robot sales in recent years, but this damper, important as it is, does not alone explain why the robotics market in the United States has failed to live up to its advance billing or why American business lags behind Japanese industry in the use of robots. Other, more fundamental forces, are at work. The one U.S. vendors come back to time and again is lack of management support for the introduction of robots.

Manufacturing managers and engineers, they claim, do not fully appreciate the capabilities this form of automation can bring to the plant floor, while upper management does not understand the beneficial impact of robotics on corporate balance sheets -- increased productivity, reduced direct labor costs, lower material costs (because there are fewer rejects and better machining tolerances), decreased capital costs (since robots can be reprogrammed to respond to changes in manufacturing requirements), improved working conditions and safety standards, and better product quality. American robot suppliers maintain as well that top U.S. management, with its short-term outlook, demands an unreasonable rate of return or payback period on robotics equipment. Few robot applications, it is noted, have the one-year payback often required by high-level executives. Two to four years are more typical payback periods, depending on total robot costs (including accessories and installation), the nature of the application, and the number of shifts the equipment is used or the volume of production.

Management in Japan at all levels continues to be more supportive of the robotization of production processes than its American counterpart, argues Paul Aron of Daiwa Securities America Inc., the leading U.S. authority on the Japanese robotics industry. Japanese managers have been quick to recognize the wide applicability, flexibility and cost effectiveness of robots. To a large extent, this acceptance reflects the longer-range outlook of Japanese companies, but it has also been helped by the makeup of Japanese management. Unlike American managers, who tend to be specialists, Japanese managers often are production-oriented generalists who are more comfortable with the changes brought about by robots.

While management support has been crucial, Mr. Aron also credits the large number of robots in use in Japan to that country's labor practices. The reaction of Japanese workers to the introduction of robots has gone beyond mere acquiescence to active acceptance, in part because robots have been used most extensively for jobs that humans find monotonous, physically taxing and/or physically hazardous. More importantly, Japanese labor as a group has not been threatened with the prospect of automation-related layoffs because the large

corporations that have been the major users of robots are willing to assume responsibility for job retraining. In addition, employees in Japan have an incentive to welcome robots: their semiannual bonuses are ultimately tied to the company's profits, and profits are generally boosted by the installation of robots.

Different attitudes toward the installation of robots in the United States and Japan do not singlehandedly explain why this form of automation has been more readily adopted in Japan. Industry observers point out in addition that American robot manufacturers have tended to concentrate on developing the most sophisticated products possible with the existing technology, in the process producing robots that are unnecessarily complex and expensive for most applications. Japanese makers, in contrast, built a big market by starting off with manual manipulators, fixed sequence robots and other relatively simple, low-cost devices targeted at practical applications and then shifting to more sophisticated equipment (see Table 2).

Partly as a consequence of this strategy, Japanese robot builders have developed a broader market for their product than their American competitors. The automotive industries of the United States and Japan were the early leaders in the introduction of robots. Car and truck manufacturers continue to be the dominant end market in this country, owning an estimated 50 to 60 percent of the 7,200 robots in operation at the end of 1982. In Japan, though, electric appliance and electronics firms moved ahead of motor vehicle producers as robot purchasers in 1980. Since that time, the electric/electronics industry has installed 30 percent-plus of the robots made in Japan each year, while automotive makers have bought just under 30 percent.

The home appliance industry is probably the second largest market for robots in the United States, but it is a distant second. Running third, apparently, are aerospace companies. Even further behind are makers of plastic products, heavy industrial and commercial equipment, and fabricated metal products -- industries that are important robotics users in Japan, accounting individually for roughly 5 to 10 percent of shipments in recent years. In fact, 12 Japanese industries, including precision equipment, nonferrous metals, steel and chemicals, installed 100 or more JIRA-defined robots in 1982.

While both American and Japanese robot manufacturers claim that current robot applications across all industries do not come close to tapping the technology and expertise builders have to offer, robots have been put to a wider variety of uses in Japan than here. The most striking difference between the two countries is the extensive use of robots in Japanese assembly operations. Assembly robots represent the largest category of shipments by value, anywhere from one-fifth to a third in recent years. In the United States, where assembly robots are just beginning to experience rapid growth, spot welding is the most pervasive application, followed by materials handling, machine loading and unloading, casting, and spray painting and coating. These handling and process applications are well established in Japan, too, but so are such other uses as arc welding and drilling and deburring.

Japanese robot manufacturers have also been more successful in convincing firms of all sizes to invest in robotics equipment. No more than a handful of large corporations, including the Big Three auto makers, is said to

operate most of the robots in use in the United States. Big companies are still the major market in Japan as well, but the user profile is changing as more small- and medium-sized businesses install robots.

American observers often retort that this diversification has more to do with the availability of Japanese government financial incentives than skillful marketing by robot vendors. This charge has some validity, but it ignores the fact that direct government benefits for robot users only became available in 1980, years after the robotics industry had passed its infancy.

Under the 1978 "Special Measures Law Concerning the Promotion of Specific Machinery and Information Industries," buyers of robots can take extra depreciation in the first year. The added depreciation allowance, amounting to 13 percent of the purchase price in FY 1980 and FY 1981 and 10 percent as of FY 1982, can yield substantial tax savings on qualifying robots, generally limited to fairly sophisticated devices. Under another provision of this law, also effective from FY 1980, small- and medium-sized firms can obtain low-interest loans through the Small Business Finance Corp., a government-owned financial agency, to purchase robots to improve occupational safety. Central and local governments also provide interest-free loans for small- and medium-sized companies installing robots and other automated equipment to compensate for skilled labor shortages.

In a complementary 1980 move backed by the government, 24 robot makers, ten insurance companies and seven leasing firms formed the Japan Robot Leasing Co., Ltd. (JAROL) to help small- and medium-sized manufacturers that cannot afford to buy robots outright. Using low-cost loans from the government-owned Japan Development Bank as well as funds supplied by the Long-Term Credit Bank of Japan, Ltd., Industrial Bank of Japan, Ltd. and city banks, JAROL buys robots from participating builders and then leases them to qualified buyers on terms more advantageous than those offered by private leasors or large robot manufacturers. Equally important, JAROL provides systems engineering and consultant services to its clients.

New Makers Jump into the Japanese Market

The structure of the Japanese robotics industry has changed considerably in recent years. In the late 1970s, the 140 or so companies making robots were, with a few exceptions, firms listed on the first section of the Tokyo Stock Exchange. The market leaders included some of Japan's biggest corporations -- corporations that generated only a small fraction of their total revenues from robot sales. The number-one maker was Kawasaki Heavy Industries, Ltd., a licensee of the leading American builder, Unimation Inc., which had secured the top position by dominating the Japanese market for spot welders, the first widespread robotics application. Occupying second place was Yaskawa Electric Manufacturing Co., Ltd., the early Japanese leader in arc welders. Hitachi, Ltd. was a close third with its line of robots for multipurpose applications, arc welding and spray painting, followed by Fujitsu Fanuc Ltd., a builder of machine loading and unloading robots. Among the second-tier suppliers were three makers of spray painting robots -- Kobe Steel, Ltd., Mitsubishi Heavy Industries, Ltd. and Tokico, Ltd. -- and two producers of arc welders -- Shin Meiwa Industry Co., Ltd. and Nachi-Fujikoshi Corp. Aida

Engineering, Ltd. and Dainichi Kiko Co., Ltd., both manufacturers of robots for materials handling applications, were also in this group of contenders.

By 1983, new entrants, often small businesses, had swelled the ranks of Japanese robot manufacturers to an estimated 250 companies. Among these makers are a large number of companies -- perhaps as many as 80 -- that only build robots for installation in their own plants and those of subcontractors. Auto makers are a prime example of this type of builder, although some big electronics companies are also on the list.

Other firms that initially developed robots for in-house use have since discovered that there is a commercial market for their equipment. These new vendors include several large electronics manufacturers -- most notably, Matsushita Electric Industrial Co., Ltd., Mitsubishi Electric Corp. and NEC Corp., which have emerged as leading suppliers of assembly robots. Competing with them in this application market are entrants from such disparate industries as precision equipment (Sankyo Seiki Manufacturing Co., Ltd. and Suwa Seikosho Co., Ltd.), industrial fasteners (Nitto Seiko Co., Ltd.), materials handling (Hirata Industrial Machineries Co., Ltd.), and writing instruments (Pentel Co., Ltd. and Sailor Pen Co., Ltd.).

Faced on all sides by new competitors, Japan's traditional robot leaders have gone on the offensive. Hitachi has added four assembly robot models to its lineup of multipurpose, arc welding and spray painting robots. Fanuc has expanded its series of machine loading and unloading robots and introduced three types of assembly robots plus a line of general-purpose robots for applications including arc and spot welding. Yaskawa, which has lost market share in the arc welding market to established makers like Hitachi, Shin Meiwa and Osaka Transformer Co., Ltd. as well as to newcomers such as Matsushita Electric, has taken a different tack, upgrading its products with new sensors and controllers. Kawasaki Heavy Industries, challenged in the spot welding market by Mitsubishi Heavy Industries, Nachi-Fujikoshi and several other makers, has adopted a similar strategy of product enhancement; in addition, it is pushing sales of other products, particularly assembly robots.

Strategies such as these have helped old-guard robot manufacturers to expand production and sales but not necessarily to maintain their earlier market positions. A Nihon Keizai Shimbun survey conducted over the past three years underscores how fluid production rankings have become. In the 1982 business year (generally the period ending in March 1983), Matsushita Electric turned out to be the top producer, although most of its output was apparently used in-house or went to subsidiaries and subcontractors. Hitachi was estimated to be the number-two manufacturer, followed closely by Kawasaki Heavy Industries, Yaskawa and Fanuc. Matsushita Electric was expected to hold on to its new leadership position in the 1983 accounting period, but Fanuc was projected to move into the second spot, ahead of Hitachi. By fiscal 1985, the survey also suggested, these three manufacturers could be in a fight for the number-one ranking, with Dainichi Kiko, Mitsubishi Electric and Kobe Steel contesting Kawasaki Heavy Industries and Yaskawa for the other top positions.

Suppliers Crowd into the U.S. Marketplace

The U.S. robot industry, even more than its offshore competitor, has been swept by structural change in the past five years. As recently as the start of this decade, Unimation, then a Condec Corp. subsidiary, and Cincinnati Milacron Inc., the nation's top machine tool maker, ruled the small American robot market. Unimation's leadership position was built on the success of its advanced, multipurpose Unimate series of robots, which have found widespread use as spot welders and in handling applications. Its market role was further enhanced in 1979 with the commercial introduction of the Puma series, described as the first robot line designed for close-tolerance assembly work and small parts handling, and the later announcement of a portable arc welder. For its part, Cincinnati Milacron, which only entered the robot market in 1977, quickly rose to the number-two spot on the strength of its sophisticated T3 models -- a line used in a wide variety of applications, including spot and arc welding, machine loading and unloading, parts handling and assembly.

Rivals to Unimation and Cincinnati Milacron in the late 1970s numbered no more than ten companies. The third-largest maker was Prab Robots, Inc., which first made a name for itself manufacturing low-cost, nonservo-operated handling robots and then moved into the high-technology area with the acquisition of the Versatran line from AMF Inc. Prab's competition in the market for medium-technology handling robots came from the number-four U.S. manufacturer, Copperweld Robotics Inc. (then Auto-Place, Inc.), a Copperweld Corp. unit. Rounding out the list of main players in the American robotics market were two distributors of imported robots: ASEA Inc., which sold its Swedish parent's line of versatile, high-performance robots, and DeVilbiss Co., a subsidiary of Champion Spark Plug Co., which marketed spray painting robots made by Trallfa Nils Unddrhaung of Norway.

The prospect of snowballing robot sales in the 1980s altered this face of the U.S. industry by attracting a new breed of competitor -- small startup firms, generally backed by venture capital. Many of these newcomers had their eye on the high-technology end of the business, like Automatix Inc., a Burlington, Massachusetts maker of turnkey robotics systems for small parts assembly, inspection and arc welding; Intelledex Inc. of Corvallis, Oregon, which produces high-performance assembly robots for use in the electronics industry; and Hebron, Ohio-based Advanced Robotics Corp., a maker of arc welders. Other startups have targeted the market for less sophisticated equipment, including American Robot Corp., a Pittsburgh, Pennsylvania company making robots for light applications, including assembly, and International Robomation/Intelligence of Carlsbad, California, a manufacturer of "affordable" robots for simple handling applications. Although in the minority, some newcomers have developed robots for a range of applications, such as Cybotech Corp., a joint venture between Ransburg Corp. and French auto maker Regie Nationale des Usines Renault, which turns out products for arc welding, spray coating and parts inspection.

Waiting in the wings while the startups made their move into the robotics market were a number of potentially more formidable American competitors -- big corporations like General Electric Co., Westinghouse Electric Corp., International Business Machines Corp., Bendix Corp., GCA Corp., United Technologies Corp. and General Motors Corp. All of these companies had

robotics development programs underway. IBM and GM had gone a step further, manufacturing robots for in-house use, while Bendix and GCA had developed products for the commercial market. But when these corporate giants decided to jump into the market in 1981 and 1982, their admission tickets, in most cases, were robots sourced from foreign, mainly Japanese, builders.

GE's bid to become a major player in the U.S. robotics market is centered on the Hitachi lineup of multipurpose, arc welding, spray painting and assembly robots. These products are supplied under a seven-year pact signed in mid-1981 that gives the American company manufacturing rights in addition to nonexclusive worldwide marketing rights. Filling out the GE line are an assembly and parts handling robot made by Italy's DEA S.p.A. and equipment from Volkswagenwerk AG for materials handling and process applications.

Not to be outdone by its rival in the electric machinery market, Westinghouse also turned to multiple foreign sources of supply, concluding nonexclusive marketing and licensing pacts for arc welders with Mitsubishi Electric and Komatsu, Ltd. in the spring of 1982 after earlier initialing the same type of agreement with Italy's Olivetti Group for an assembly robot. These models supplement Westinghouse's own line of multipurpose robots.

Bendix and GCA have both tried to carve out positions in the markets for materials handling and assembly robots by combining their own products with Japanese-made equipment. Bendix is tied up with Yaskawa under a five-year nonexclusive sales agreement signed in late 1982, while Dainichi Kiko is supplying GCA, its exclusive North American distributor since early 1982. For its part, IBM has zeroed in on the expanding market for assembly robots in the electronics, appliance, cosmetics and automotive industries. Through a 1982 supply pact with Sankyo Seiki, the data processing equipment giant is offering two low-cost robots for simple assembly and materials handling operations. Complementing these products is the commercial version of IBM's in-house robot, which can handle more complex light assembly jobs than the imported equipment.

But the pairing that has permanently changed competitive conditions in the American marketplace is the mid-1982 tie-up of General Motors and Fanuc. Their joint venture, GMF Robotics Corp., offers perhaps the broadest product line of any U.S. vendor: robots for machining operations, assembly and special-purpose applications like arc and spot welding and parts handling that are made by Fanuc, plus a GM-designed painting robot. More importantly, GMF has quickly become the leading supplier to GM, the biggest robot user in the United States. For Unimation, Cincinnati Milacron, DeVilbiss and other domestic robot builders that have long counted on big sales to the auto maker, this turn of events has been a major blow. Few believe GM denials that GMF has a lock on its robot business.

Big corporations are not alone in tying up with offshore producers for robot supplies or technology. A number of startup firms have gone this route to fill out their product lines. Automatix has been licensed by Hitachi to make a multipurpose robot; it also imports an assembly robot from Hirata Industrial that is integrated into turnkey systems. Advanced Robotics markets a Nachi-Fujikoshi arc welder in addition to its own two models, while Cybotech recently agreed to handle a painting robot manufactured by Tokico. Moreover,

at least two established robot makers -- DeVilbiss and Copperweld Robotics -- have nonexclusive marketing pacts with Japanese builders. DeVilbiss is currently offering an arc welder made by Matsushita Electric, but later this year it plans to introduce another model, as well as a materials handling robot supplied by an unnamed Japanese manufacturer. For its part, Copperweld Robotics has been selling a line of Nachi-Fujikoshi robots for assembly and materials handling applications.

Other American companies have linked up with Japanese robot producers to diversify or expand their primary line of business. For example, Hobart Brothers Co., a Troy, Ohio maker of welding products, sells Yaskawa's arc welding robot, while metalworking equipment manufacturer Minster Machine Co. of Minster, Ohio distributes parts handling robots imported from Orii Corp. In addition, Fairchild Industries Inc.'s VSI Automation division has added a Nitto Seiko assembly robot to the line of Japanese-made machine tools it markets.

For these companies as well as the others, sales and/or licensing pacts with Japanese builders have an obvious advantage over in-house development of robotics technology: they provide a low-cost way to break into the business or to expand an existing market stake. Not too surprisingly, executives of many old-line robot companies charge that all these firms are doing by taking "shortcuts" into the robotics field is helping Japanese manufacturers establish beachheads here. Without a hand from GE et. al., they add, potential Japanese competitors would be saddled with the expensive and time-consuming job of setting up American distribution, technical support and service networks.

In fact, few Japanese robot manufacturers have tried to market here on their own. Those that have, like Mitsubishi Heavy Industries with its spray painting and coating robot, generally use the American subsidiaries of Japanese trading companies. Most builders instead have gone the dual distribution route, selling through a U.S. marketer and offering products under their own brand. Hitachi, Nachi-Fujikoshi, Hirata Industrial, Tokico and Shin Meiwa (which sells its arc welder through Waukesha, Wisconsin-based Generac Corp.) have adopted this strategy, for example. Other major makers rely exclusively on their tie-up partner for American sales, like Matsushita Electric (DeVilbiss), Dainichi Kiko (GCA) and Mitsubishi Electric (Westinghouse). Yaskawa has taken a slightly different approach, marketing through five different U.S. companies including Bendix and Hobart Brothers.

U.S. Market Too Crowded?

The influx of new producers into the U.S. industry over the past five years has boosted the number of companies manufacturing robots to over 50. Another 30 or so firms are marketing products imported from abroad. With the recession limiting demand across all major application markets, the flood of new product offerings had a predictable result: prices dropped and profits evaporated. No manufacturer was immune to these developments, but industry newcomers, weighted down by heavy initial development, manufacturing and marketing expenses, were particularly hard hit.

Poorer-than-expected market conditions did produce some casualties. Last fall, Bendix dropped out of the manufacturing end of the business, although it will continue to carry the Yaskawa line. Late in the year,

Copperweld put its robotics subsidiary up for sale, in effect ending its marketing agreement with Nachi-Fujikoshi. Recently, Nordson Corp., an Amherst, Ohio maker of painting and coating robots that also distributed a line of Yaskawa sealing robots, decided to pull out of the market. In addition, ownership of Unimation changed hands in February 1983 when Westinghouse took over the industry leader. Still, the major shakeout most industry watchers had predicted never occurred.

Even with the resumption of strong sales, analysts say, the U.S. robot market cannot support all the companies now jockeying for position. Consolidation might be slow, they add, but major dropouts are inevitable. Who will the survivors be? Certainly, most people agree, the companies that currently dominate the industry -- Unimation, Cincinnati Milacron, Prab and fast-rising GMF, as well as DeVilbiss and ASEA, both of which have become onshore manufacturers.

Other successful companies, it is generally predicted, will come from one of three groups of suppliers. The first consists of high-technology niche companies like Automatix that offer "value added" turnkey systems. Another set of players will be drawn from the ranks of firms now positioning themselves in the fledgling factory automation field -- GE, Westinghouse, IBM and other companies that have deep financial pockets, sophisticated product and process technology, systems and applications expertise, and marketing skills. The final group of competitors will be low-cost, high-volume manufacturers. Most industry watchers assume that these makers will be Japanese, but the question is, which ones.

For further information, contact Susan MacKnight.

The opinions expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.

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Table 1: U.S. Apparent Domestic Consumption of Robots, 1979-83*

(value in thousands of dollars; quantity in units)

	1979	1980	1981	1982	1983**
Value					
Shipments	$28,077	$64,059	$113,385	$142,845	$168,654
Exports	8,909	20,766	23,309	20,322	33,738
Imports	3,751	4,225	10,620	15,097	28,946
Trade Balance	5,158	16,541	12,689	5,225	4,792
Apparent Domestic Consumption	22,919	47,518	100,696	137,620	163,862
Ratio of Exports to Consumption	38.9%	43.7%	23.2%	14.8%	20.6%
Ratio of Imports to Consumption	16.4%	8.9%	10.5%	11.0%	17.7%
Quantity					
Production	614	1,118	1,993	2,585	3,234
Exports	173	340	413	428	631
Imports	66	73	156	376	999
Trade Balance	107	267	257	52	-368
Apparent Domestic Consumption	507	851	1,736	2,533	3,602
Ratio of Exports to Consumption	34.1%	40.0%	23.8%	16.9%	17.5%
Ratio of Imports of Consumption	13.0%	8.6%	9.0%	14.8%	27.7%

*Data were derived from International Trade Commission questionnaries sent to U.S. producers and importers. Responses were received from 21 producers that represent more than 90 percent of the value of U.S. shipments and from 13 importers that account for virtually all U.S. imports.

**July-December 1983 data were estimated by producers.

Source: U.S. International Trade Commission, Competitive Position of U.S. Producers of Robotics in Domestic and World Markets (USITC Publication 1475), December 1983.

Table 2: Japan's Production of Robots, 1979-82

(value in thousands of dollars*; quantity in units)

	1979	1980	1981	1982
Value				
Manual Manipulators	$ 8,835	$ 12,362	$ 13,676	$ 11,857
Fixed Sequence Robots	86,753	102,743	108,583	73,636
Subtotal	95,587	115,105	122,259	85,493
Variable Sequence Robots	33,568	41,993	65,285	77,438
Playback Robots	30,360	69,619	151,392	214,788
Numerically Controlled Robots	7,963	96,119	72,912	102,742
Intelligent Robots	16,875	9,530	48,526	78,623
Subtotal	88,765	217,261	338,116	473,592
Peripheral Equipment and Parts	9,227	13,504	28,340	36,892
Total	193,579	345,870	488,714	595,977
Quantity				
Manual Manipulators	1,051	1,942	964	1,197
Fixed Sequence Robots	10,721	13,438	12,923	8,648
Subtotal	11,772	15,380	13,887	9,845
Variable Sequence Robots	1,224	1,343	2,478	4,311
Playback Robots	662	2,027	3,928	6,672
Numerically Controlled Robots	89	992	1,138	2,001
Intelligent Robots	788	131	638	1,953
Subtotal	2,763	4,493	8,182	14,937
Total	14,535	19,873	22,069	24,782

*The following average annual exchange rates, which reflect the midpoint on the Tokyo spot foreign exchange market, were used to convert the yen production figures: 1979, Y219.14; 1980, Y226.75; 1981, Y220.54; and 1982, Y249.05.

Source: Japan Industrial Robot Association